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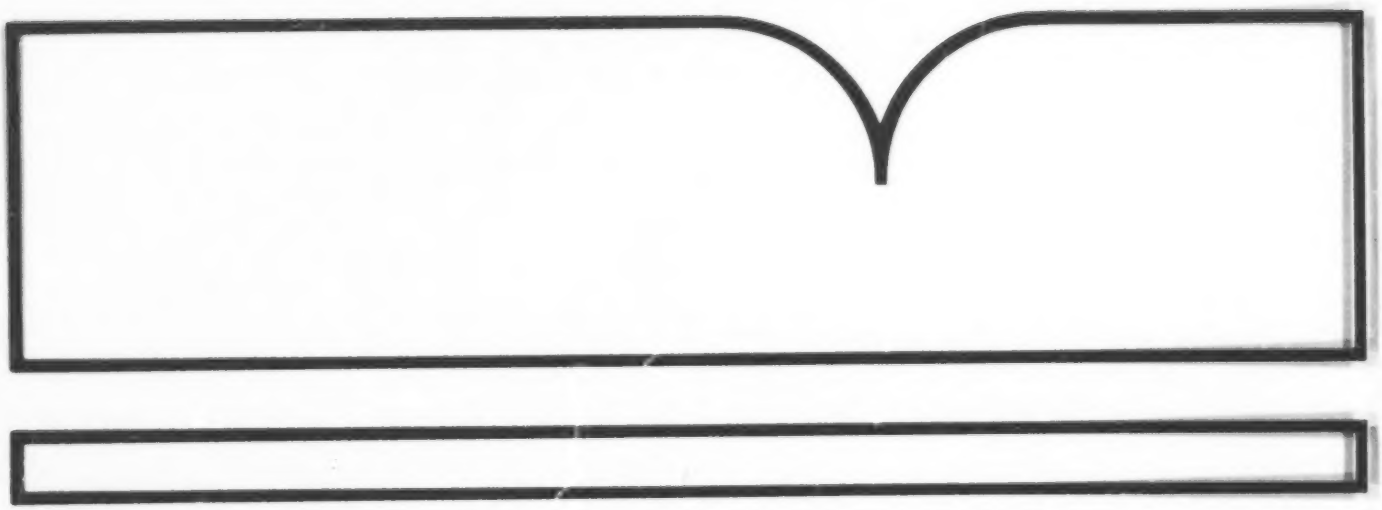

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ELECTROSTATIC STIMULATION OF FABRIC FILTRATION--AN UPDATE

by

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16. ABSTRACT The paper gives results of an investigation of the concept of electrostatic stimulation of fabric filtration (ESFF) on a slipstream of a pulverized-coal-fired boiler using reverse-air-cleaned woven fiberglass filter bags. Operation was demonstrated using ESFF at a glass-to-cloth ratio (G/C) of 6. An un-electrified control house was operated simultaneously at a G/C of 3. Under these conditions, the ESFF house maintained a pressure drop equal to or less than that of the control baghouse. In addition to reducing the filter cake pressure drop, ESFF was observed to apparently have long term benefits in preventing irremovable dust buildup in the fabric.

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Electrostatics	Dust	Stationary Sources	20C	11G
Filtration	Glass Fibers	Fabric Filters	07D	11B
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ABSTRACT

The concept of electrostatic stimulation of fabric filtration (ESFF) has been investigated on a slipstream of a pulverized-coal-fired boiler using reverse-air-cleaned woven fiberglass filter bags. Operation was demonstrated using ESFF at a gas-to-cloth ratio (G/C) of 6. An un-electrified control house was simultaneously operated at a G/C of 3. Under these conditions the ESFF house maintained a pressure drop equal to or less than the control baghouse. In addition to reducing the filter cake pressure drop, ESFF was observed to apparently have long term benefits in preventing irremovable dust buildup in the fabric.

INTRODUCTION

This paper describes development activities from May 1981 to March 1982 using a pilot scale, slipstream fabric filter employing electrostatic stimulation of fabric filtration (ESFF).

The ESFF concept is based on laboratory scale tests at the Textile Research Institute (TRI) as reported by Lamb and Costanza[1]. The TRI concept of ESFF consists of applying an electric field parallel to the surface of the fabric through use of electrodes located at the upstream surface of the filter fabric. Figure 1 is a schematic of a TRI electrode "harness" located on the outside of a pulse cleaned bag and electrically connected so that alternate electrode wires are at high electrical potential.

A team composed of Research Triangle Institute (RTI), ETS, Inc., and TRI, under contract to the U.S. EPA, is evaluating this concept at pilot scale. The pilot scale program was started in October 1979. The first year's primary objective was to verify the TRI laboratory results under actual flue gas conditions. RTI, as prime contractor, has directed the technical effort and performed initial electrical hardware development and construction. ETS, Inc. has designed, built, installed, and is operating the pilot unit. ETS and RTI are further developing the ESFF hardware. The pilot plant is installed on a slipstream of a pulverized-coal boiler at the E.I. DuPont de Nemours & Company plant, Waynesboro, Virginia.

The pilot unit was designed to operate in either the pulse-jet (outside collection) or reverse air (inside collection) cleaning mode. The baghouses were first operated as pulse-jet collectors. The principal conclusions of the pulse-jet work, as reported previously,[2,3] were:

1) At any given face velocity, the pilot ESFF baghouse had a reduced residual pressure drop and a reduced rate of pressure drop increase when compared to the pilot conventional baghouse.

2) The pilot ESFF baghouse could be operated in a stable fashion at face velocities up to about twice the stable operating conditions for the pilot conventional baghouse.

3) A reduction in total annualized cost of about 30 percent was estimated for an industrial boiler application utilizing an ESFF baghouse at twice the conventional face velocity.

4) Particulate emissions from the two baghouses were not significantly different.

5) The electrode configuration developed in the course of the study, a combination pulse-jet cage/electrode, was feasible and had potential for commercial use.

In May 1981, the pilot plant was converted to reverse-air cleaning. This paper summarizes the development activities and reports preliminary results and conclusions based on the work from May 1981 to March 1982.

The Pilot System

The pilot system provides the capability of simultaneous monitoring of the ESFF effect through use of two identical baghouses receiving their inputs from a common slipstream. One baghouse is supplemented with electrical enhancement equipment; the other is not.

Figure 2 is an isometric drawing of the pilot unit, and Figure 3 shows the system schematic. Each baghouse can accept up to 9 reverse-air cleaned bags each 20.3 cm (8 in.) in diameter and 224 cm (8 ft) long, or up to 13 pulse cleaned bags, 11.7 cm (4-5/8 in.) in diameter and 224 cm (8 ft) long.

The provision of parallel control and experimental units is an important feature of the pilot plant in that it permits operation in either of two modes, parallel or separate. In parallel operation, both baghouses have the same inlets, compensating for the cumulative effect of varying inlet conditions. Any differences between the two units, either intentional or unintentional, can be evaluated by parallel operation. Future work is planned where separate tests will be conducted in each baghouse after sufficient experience is in hand to negate the further need of a "control" baghouse.

The pilot unit is installed on a slipstream from an industrial boiler baghouse. Four pulverized-coal boilers are used with a normal load of about 160,000 kg/hr (350,000 lb/hr) of steam. The coal fed to the boilers changes frequently, with sulfur content varying from less than 1 percent to about 2 percent, and ash content ranging from 5 to

15 percent. The boilers are sometimes co-fired with oil. Inlet dust loadings at the pilot plant have varied from 0.6 to 5 g/scm (0.25 to 2 gr/scf); 0.7 g/scm (0.3 gr/scf) is typical.

ESFF Test Hardware

The electrical power requirements of the ESFF system are very low. The power consumption measured by TRI and confirmed in the pilot system is about 1 W/m^2 (0.1 W/ft^2) of cloth. This ESFF power requirement is equivalent to approximately 0.1 in. of water pressure drop at a G/C of 6.

The electrical system used in the pilot unit consisted of a variable DC power supply (0 to 20 kV at 5 mA) for each of five power supply networks. Current and primary voltage were measured separately in each network. Current limiting and meter protection circuits were used.

The electrode designs utilized to date have been based on the combination cage/electrode developed during the pulse-jet work. Again, these cages were placed on the clean side of the fabric, not the outside, so as to not restrict cleaning of the bag and to avoid dirt buildup on the cage. These early cages, constructed of welded 1/8-in. (0.318 cm) rods and referred to as "rigid cages," exhibited two problems: first, fabric wear was observed at the insulator locations; and second, the wire spacing of 2.5 cm coupled with insulator limitations limited field strength to about 4 kV/cm. New cages were fabricated using 34, 1/8-in. diameter electrodes (1.68 cm spacing). These electrodes were located by woven fiberglass straps having sewn-in pockets. These cages are referred to as flexible cages, since the electrode/strap assembly is quite flexible prior to installation on the bags.

Fiberglass bags were used for the entire reverse-air test series.The bags were 20.3 cm (8 in.) in diameter and 224 cm (8 ft) long; no anti-collapse rings were used. These bags were made of J. P. Stevens Style No. 648, 17 oz (482 g) texturized fiberglass fabric with a 10 percent Teflon B finish. Each bag was tensioned to 40 lb (18 kg) using a conventional tensioning spring.

Results and Observations

Electrostatic stimulation of fabric filtration has two primary effects on filter behavior when compared to conventional filtration at the same G/C: (1) the average pressure drop is reduced through a combination of lower residual pressure drop and a reduced pressure drop rise during a filtering cycle; and (2) the ESFF baghouse can operate at a higher stable G/C.

To define and compare the effects on pressure drop rise during a filtering cycle, a figure of merit called PDR (pressure drop ratio) is used. PDR compares the beginning and ending ΔP across one cleaning cycle using electrostatic enhancement with the comparable ΔP change without electrostatic enhancement.

PDR is defined as:

$$\frac{(\Delta P_f - \Delta P_r)\ \text{ESFF}}{(\Delta P_f - \Delta P_r)\ \text{control}}$$

where ΔP is the pressure drop across the bags,

f refers to the final state (just prior to cleaning), and

r refers to the residual state (just after cleaning).

For an idealized filter cycle, in which the bag pressure drop increases linearly with time and for constant dust loading from ΔP_r to ΔP_f, it can be shown that:

$$\text{PDR} = \frac{(K_2)\ \text{ESFF}}{(K_2)\ \text{control}}$$

where K_2 is the specific cake resistance.

PDR, then, is the ratio of the flow resistance of a dust cake collected by an ESFF system to that collected by a conventional fabric filter.

Figure 4 presents typical pressure drop recordings for both the conventional and ESFF pilot baghouses in reverse-air operation. The rate of increse of pressure drop in the ESFF baghouse when compared to the conventional pilot baghouse is evident. PDR can be seen to vary depending on the length of the filter cycle, and thus is most useful for comparison of two baghouses operating with the same cleaning cycle. As the two baghouses were operating at the same face velocity when these data were obtained, the ESFF baghouse also has a reduced residual pressure drop. Thus the ESFF effect is to produce a lower average pressure drop when operated at the same filtering velocity.

The reverse-air baghouse operation was started up with a break-in period of about 1 week at a G/C of 2, with no electrical field in the ESFF baghouse. During this period the two baghouses exhibited essentially identical pressure drop characteristics, indicating that the two baghouses could be analyzed as identical baghouses in parallel. The electrical field was then put on the bags, and was left on almost continuously for the next several months.

Figures 5 and 6 present a chronological summary of the results during May and June 1981, using reverse-air bag cleaning. Field strength

and gas-to-cloth ratio were independent variables. The PDR and average pressure drop were measured for each filtering cycle and averaged for the day. The gas-to-cloth ratio was progressively increased from 2 to 6 for the ESFF baghouse; however, the control house could not operate stably above a G/C of 4.5. Note also that on May 12 and 13, when the electric field was removed, the average ΔP of the ESFF house rapidly approached that of the control house. Note particularly, that from June 15 to July 5, a 21-day period of continuous 24-hour operation, the ESFF house operated at a G/C of 6 with an average ΔP between 6.4 and 7.1 in. (16.3 to 18.0 cm) of water, while the control house operated at a G/C of only 3 and yet had an average ΔP of 7.4 to 8.3 in. (18.8 to 21.1 cm) of water.

Figure 6 demonstrates the ability of an ESFF baghouse to operate at a higher, stable G/C. Note that from June 9 to 13 the control baghouse demonstrated inability to operate stably at a G/C of 4.5; subsequently, it was reduced to a G/C of 3. Simultaneously the ESFF baghouse operated at a G/C of 6 from June 10 to 30.

Based on these encouraging results, a series of tests were undertaken to evaluate the effects of field strength and gas-to-cloth ratio on pressure drop characteristics.

Figure 7 summarizes the evaluation of field strengths of 3 and 4 kV/cm on average ΔP over a G/C ratio range of 1 to 6. This test series used the rigid cages; hence, fields above 4 kV/cm were not possible. These data show graphically the benefit derived from the ESFF effect. The conventional baghouse had a higher average ΔP where it was capable of stable operation. The advantage gained by increasing the electric field from 3 to 4 kV/cm is seen to be small.

By the end of this test series, the disadvantages mentioned previously for the rigid cage had become evident, and it was necessary to install new bags in the ESFF pilot baghouse. Figure 8 is a chronological summary of testing with new bags and the new flexible cages at field strengths up to 6 kV/cm. After a break-in period at a G/C of 2 on July 26 through 28, the G/C was increased to 4 and an electric field of 4 kV/cm resulted in an immediate decrease in the average ΔP compared to the control house. Figure 9 summarizes the results of this initial approximately 1-month test period with the flexible cages. These results indicate two things. First, little or no benefit was derived from field strengths above 3 kV/cm. Second, note the results at 0 kV/cm. As the ESFF bags were relatively new while the conventional bags had been in use since the beginning of the test program, some difference in the ΔP response of the two bag sets at zero field was expected. However, the magnitude of the difference was surprising, and suggested that something other than the electric field might be causing at least a portion of the ΔP

advantage being shown by the ESFF baghouse. An extensive investigation of the situation was undertaken, and several factors which served to exaggerate the advantage of the ESFF baghouse were identified. We are still in the process of defining a concise explanation; however, three contributing features stand out so far:

(1) As is well known, reverse-air baghouses are extremely sensitive to cleaning parameters. Although efforts had been made to favor the control house by cleaning it last, this, in fact, may have favored the ESFF house, possibly by giving it a pre-coat after cleaning. In addition, a slight leak below the tubesheet in the control baghouse, balanced by a similar sized leak above the tubesheet in the ESFF baghouse, raised the effective gas-to-cloth ratio in the conventional baghouse. These factors were quantified by experimentation, and their mathematical inclusion into the data analysis indicated that the ESFF baghouse at zero field still had a lower average ΔP than did the conventional baghouse. The same corrections reduce the size of the advantage which the data had indicated for the ESFF baghouse at the various field strengths.

(2) Recall that in May, the field was removed after 2 weeks of operation, then the ΔP's at zero field strength were essentially equal. In September, after 2 months of operation, the ESFF bags are better even with no field. This certainly suggests the possibility of a long term, cumulative effect of the electric field by reducing the buildup of un-removable dust accumulations deep in the fabric weave.

(3) During the investigation into the zero field behavior, the ESFF bags were operated for approximately 2 months without the electric field. It was noted that after this zero field operation, the low residual ΔP results which were obtained during the early operation were no longer observed. Our hypothesis is that the long term lack of an electric field allows the fabric to build an interstitial dust layer which cannot be removed by normal means, leading to the increased residual ΔPs. We are now returning to new fabric to try to verify this observation.

Conclusions

Although the evaluation of electrostatic augmentation of reverse-air-cleaned bags is not as yet complete, we feel the observations to date of primary significance are:

(1) Starting with new fabrics, ESFF operation for an extended period (21 days) at a G/C of twice (6 vs. 3) that of the control house was demonstrated.

(2) Interruption of the electric field for periods of 1 to 2 days did not eliminate the benefits of ESFF. Removal of the field for several months did diminish the benefits of ESFF upon reapplication of the field.

(3) ESFF appears to maintain the fabric in a "near new" condition relative to entrapped particles within the fabric. It is, of course, these entrapped particles that result in the residual ΔP after cleaning. This observation is consistent with earlier work, indicating that under ESFF conditions more particulate is captured near the upstream side of the fabric, and penetration into the fabric is reduced. Thus ESFF prevents, or at least significantly retards, the buildup in residual ΔP.

Future Work

Both the rigid and the flexible cages are recognized to have practical and economic limitations for full-scale filter use; hence, electrode design is continuing. The most promising concept at this time for reverse-air-cleaned applications appears to be a "woven" electrode, although this has not as yet been tested in the pilot system. Woven electrodes consist of conductive yarns woven into the warp of the fabric at the desired electrode spacing. Yarns consisting of stainless steel filaments, graphite filaments, or a graphitized high temperature nylon are now being investigated. These conductive yarns, and the techniques for weaving them, have been previously used to produce anti-static fabrics for both filtration applications and for carpets. Woven electrodes in both glass and Teflon fabrics are being investigated.

Acknowledgements

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(3) Greiner, G.P., D.A. Furlong, D.W. VanOsdell, and L.S. Hovis. "Electrostatic Stimulation of Fabric Filtration," JAPCA, 31:1125-1130, 1981 (presented at the 74th Annual Meeting of the APCA, Philadelphia, Pennsylvania, June 1981).

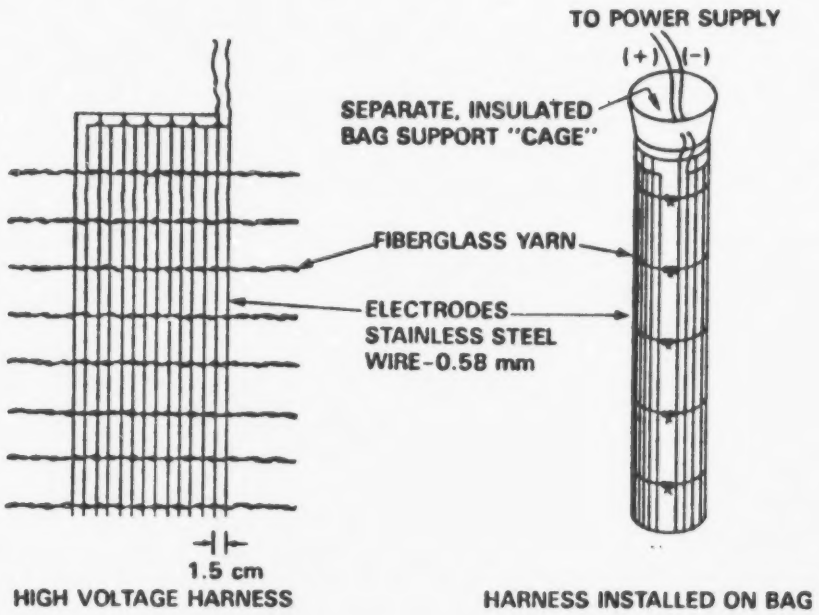

Figure 1

TRI HARNESS

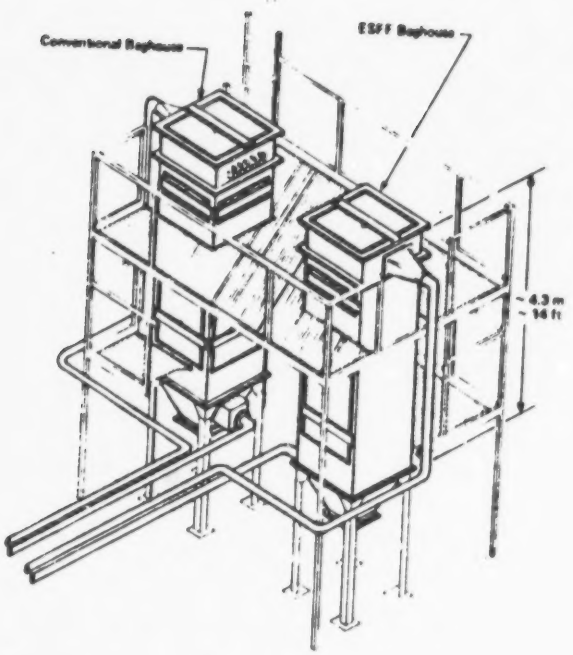

Figure 2

PILOT PLANT

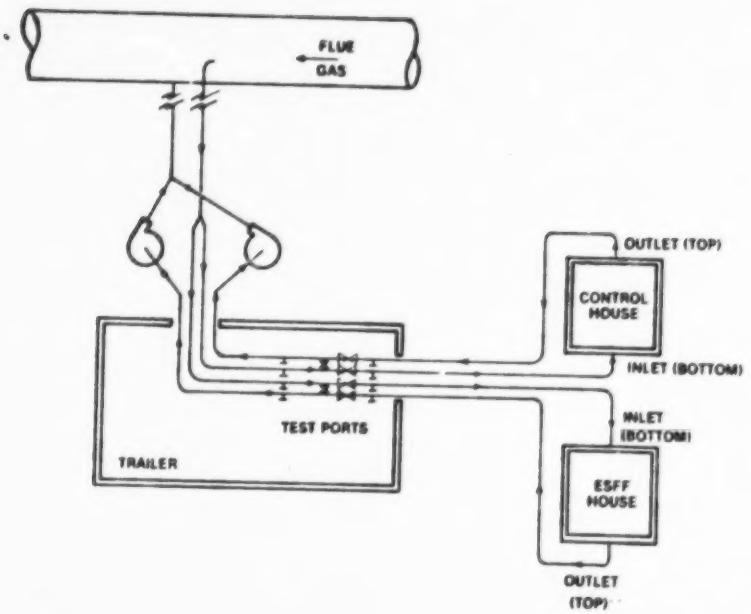

Figure 3

SYSTEM SCHEMATIC

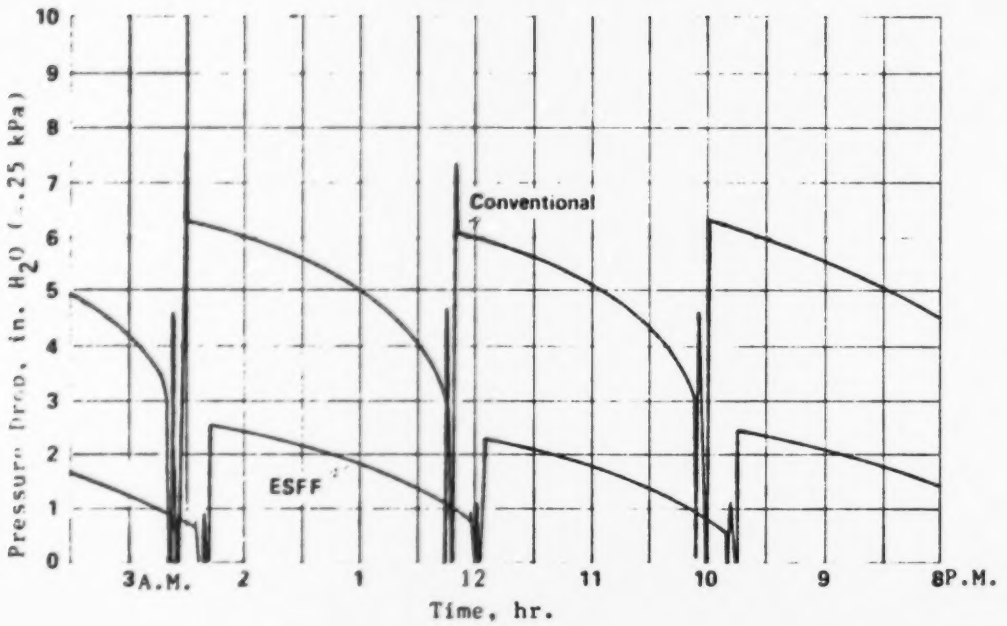

Figure 4

REVERSE AIR PILOT BAGHOUSE PRESSURE DROP TRACE

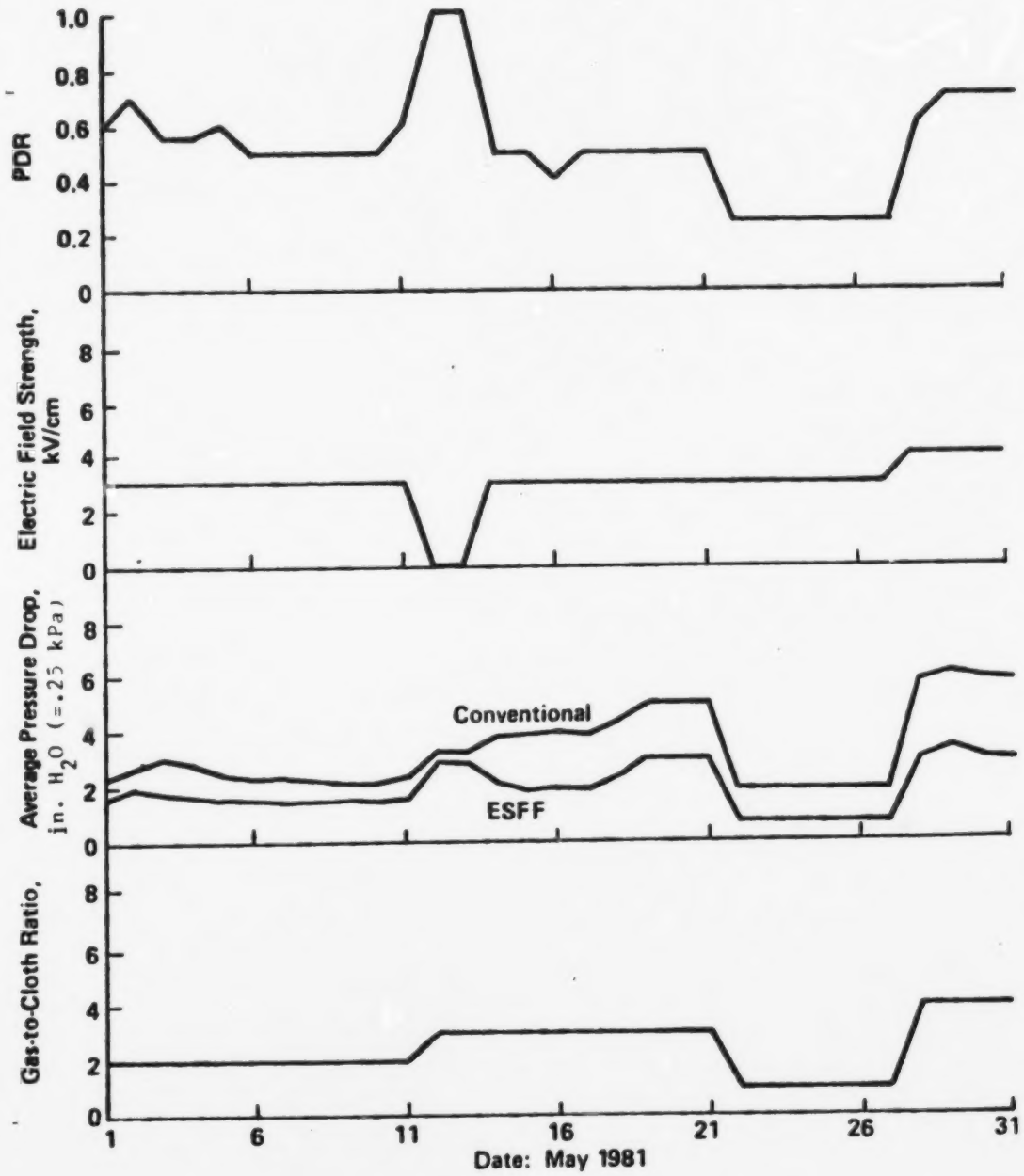

Figure 5

ESFF CHRONOLOGICAL SUMMARY, MAY 1981

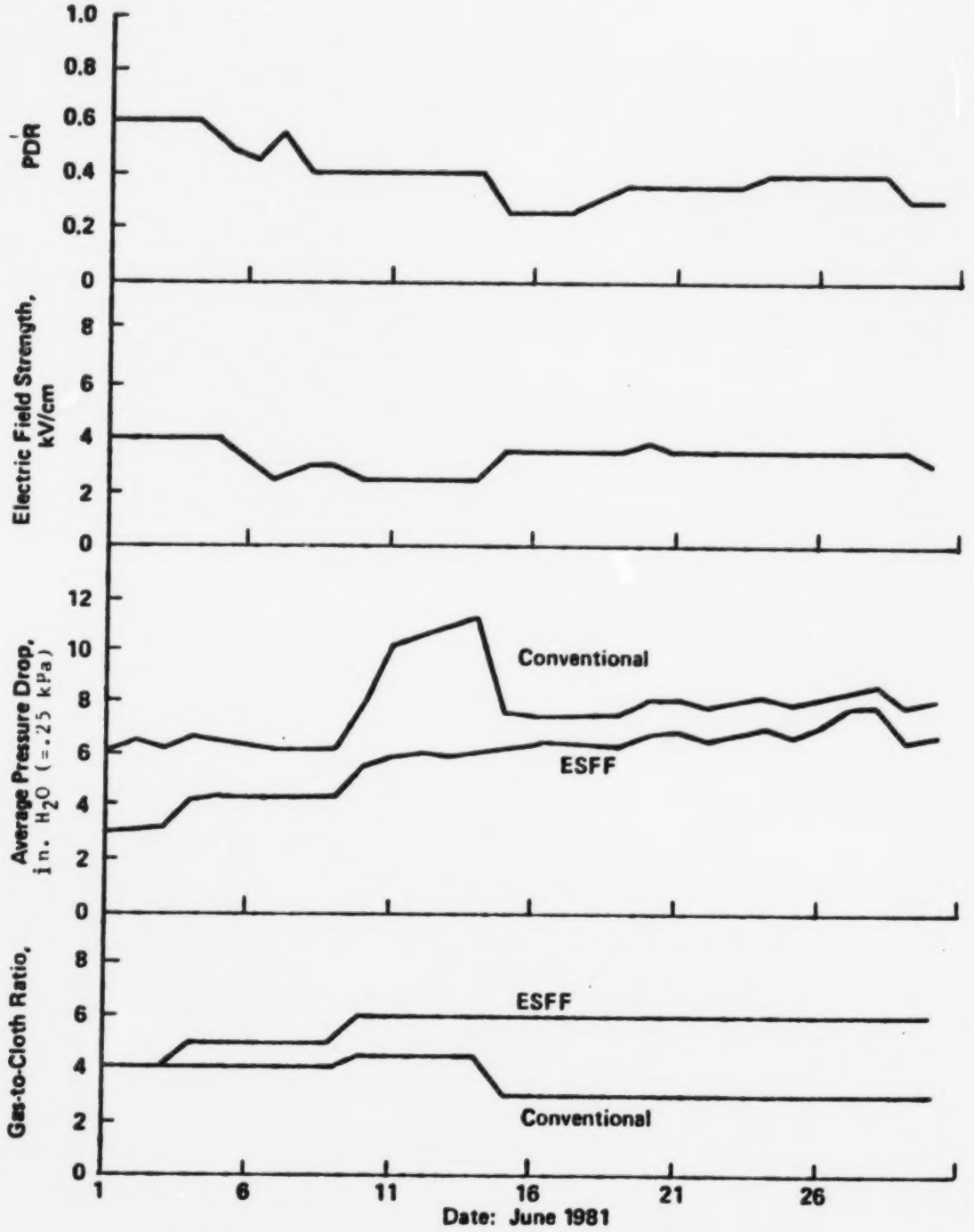

Figure 6

ESFF CHRONOLOGICAL SUMMARY, JUNE 1981

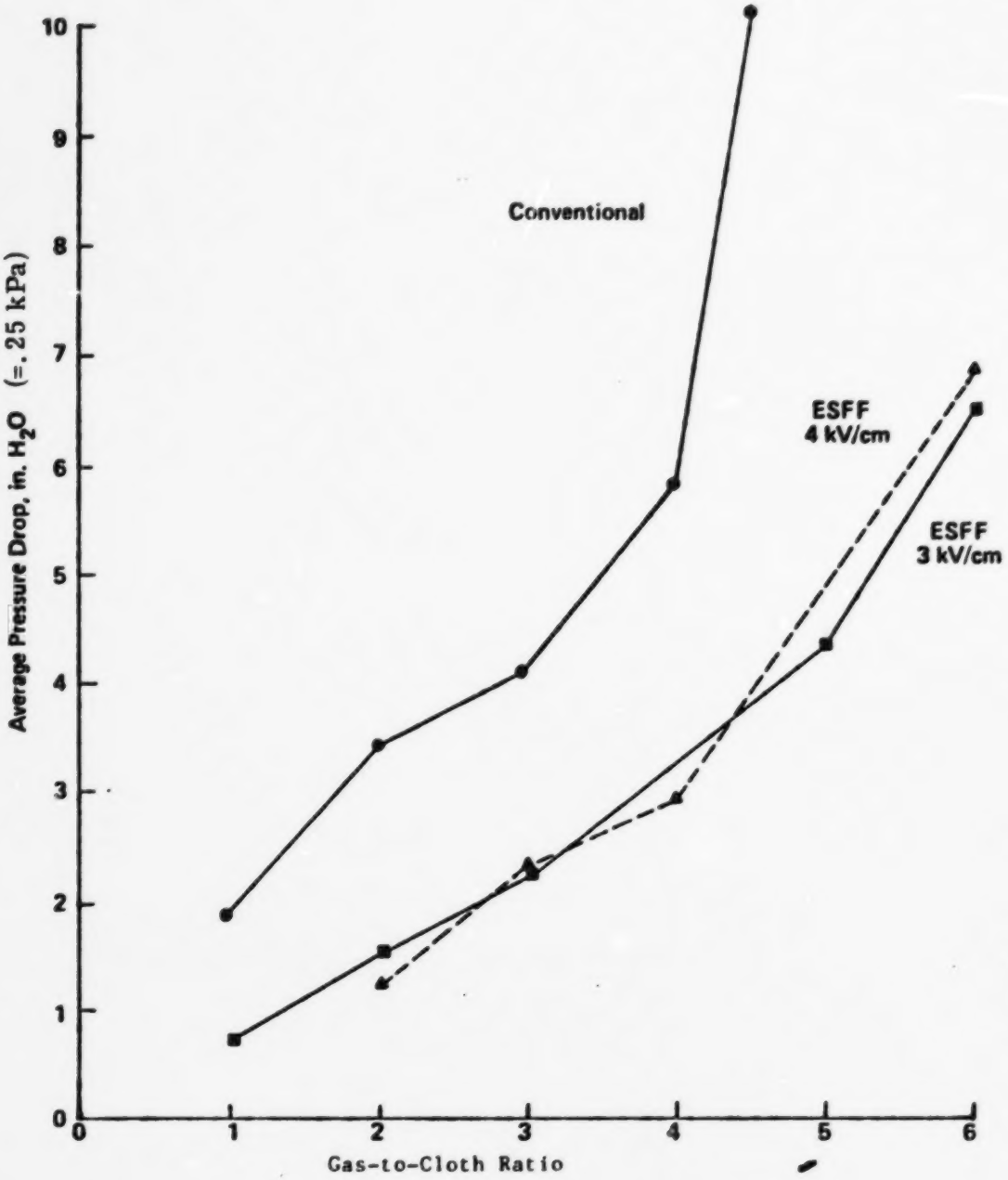

Figure 7

DELTA P AVG. VS G/C RATIO
RIGID CAGE
APRIL 24 TO JULY 15

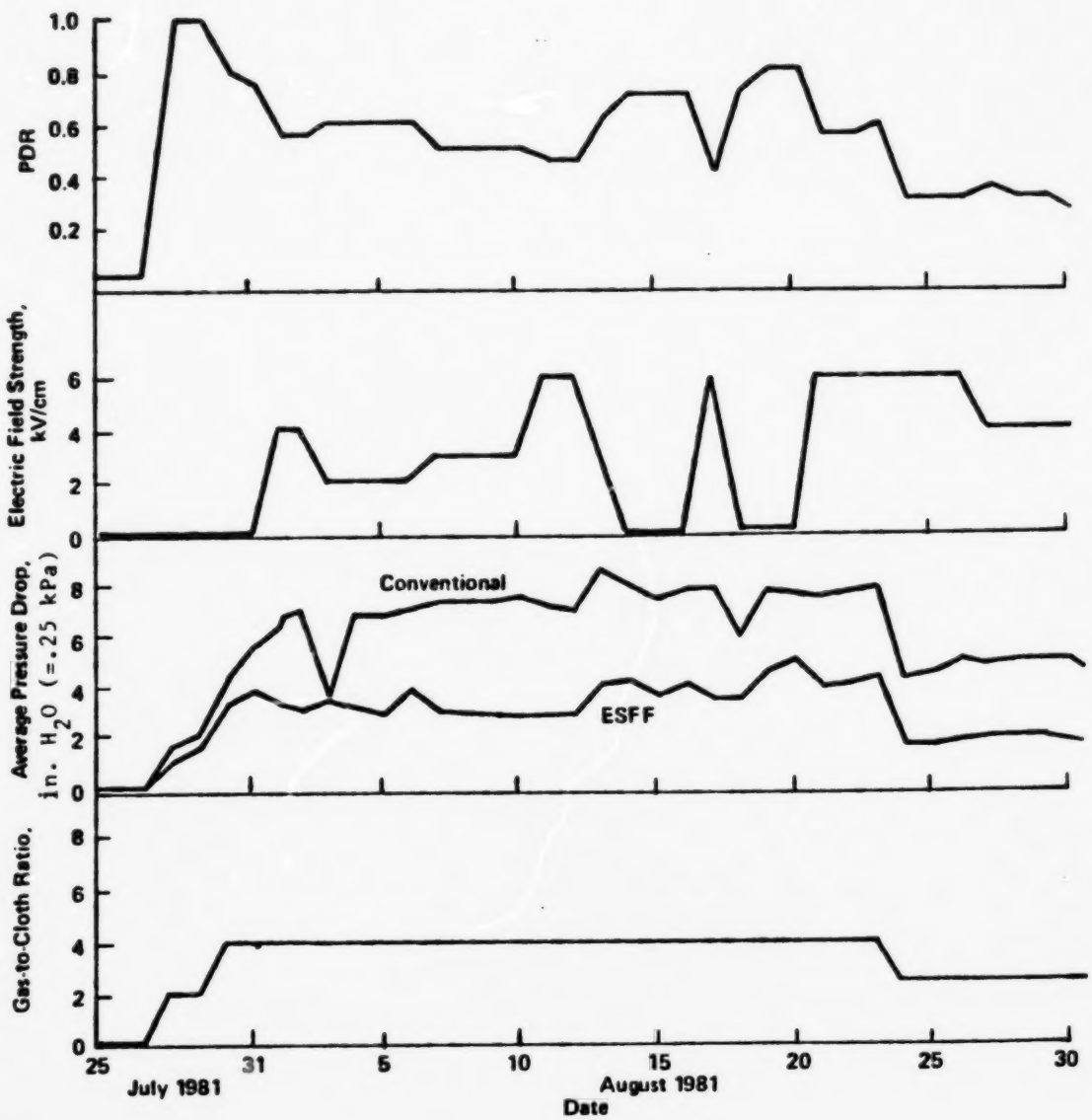

Figure 8

ESFF CHRONOLOGICAL SUMMARY, JULY 25 - AUGUST 31, 1981

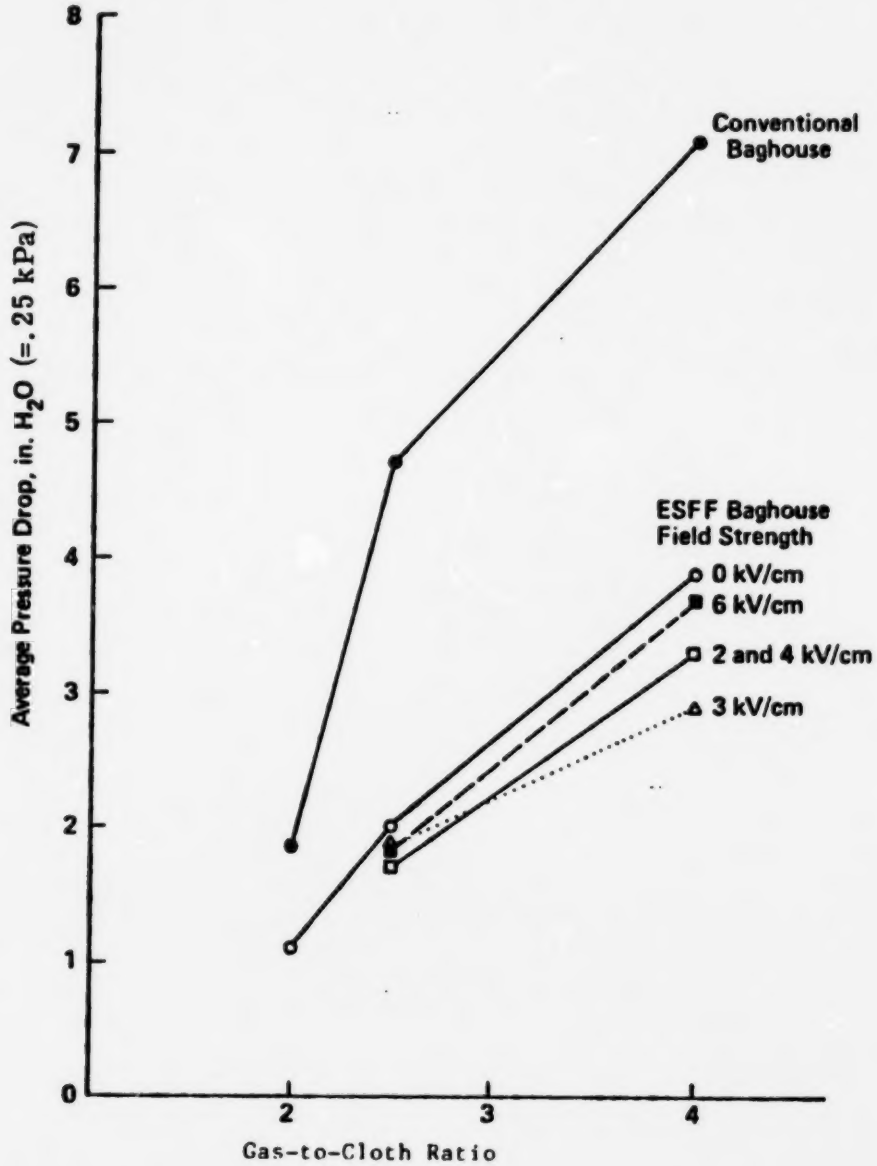

Figure 9

DELTA P AVG. VS G/C RATIO
FLEXIBLE CAGE
JULY 27 TO SEPT. 21